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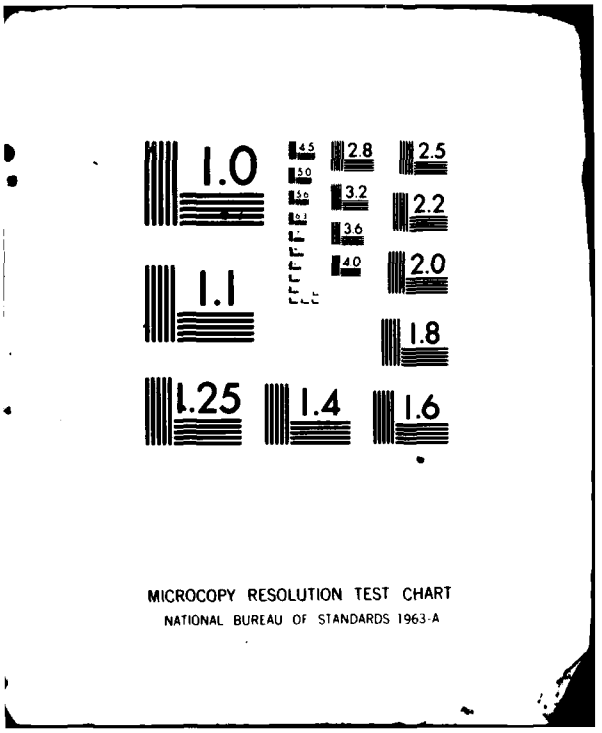
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VORTEX DYNAMICS

FINAL REPORT

N. J. ZABUSKY

2/10/82

U. S. ARMY RESEARCH OFFICE

CONTRACT DAAG29-80-K-0072

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INSTITUTE FOR COMPUTATIONAL MATHEMATICS AND APPLICATIONS
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The view, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Vortex dynamics; Euler equations; V-state scattering turbulence; hydrodynamics; contour dynamics.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Summarizes the work done studying the stability and scattering of translating V-state solutions of the Euler equations in two-dimensions. This is a computer simulation study using the method of contour dynamics, a new boundary-integral evolutionary method.

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TO: Dr. Paul Boggs
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P.O. Box 12211
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DATE: February 8, 1982

FROM: N. J. Zabusky
Department of Mathematics
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Pittsburgh, PA 15260

SUBJECT: FINAL REPORT
on Vortex Dynamics
(Contract DAAG-29-80-K-0072)
8/1/80 - 10/31/81)

1. INTRODUCTION

All research activities described below were conducted under the direction of or in collaboration with N. J. Zabusky, the Principal Investigator.

2. RESEARCH ACTIVITIES

2.1 Interaction of Coaxial V-states of the 2D-Euler Equations.

To demonstrate this concept we first undertook the coaxial scattering of a V-state and a point dipole. Successful runs for "intermediate" times were made by Dr. A. Schwartz and were published in.[3] Dr. E. A. Overman completed a large sequence of runs on the "overtaking" (head-to-tail) and "scattering" (head-on interactions) of translating V-states. These were made on the CRAY-1 at the National Center for Atmospheric Research using the inviscid contour dynamics algorithm.

We had a variety of diagnostics available to view the interaction process from varying viewpoints. These included: physical plane representation of the contours; location of the center of area (vorticity) (x_c, y_c) of the contours vs time; phaseshift diagrams namely t vs x_c and t vs y_c; curvature vs arc length and power spectra. A large investment of time was made to produce these graphics including a subroutine for making films of the physical plane representation.

A brief film showed the head-on interaction of V-states of like circulation forming a "near" V-state as described below. This was presented at the 27th Conference of Army Mathematicians (June 11, 1981) as part of an hour-long talk on this work and summarized in a preliminary version.[1]

After extensive studies we completed a paper[2] which showed:

1. Coaxial head-on interactions are "weaker" than coaxial head-tail interactions because of the geometry and fast-passage.

   a) We believe that the asymmetric state formed after the head-on interaction described above is "near" a V-state because of the very small-amplitude perimeter and curvature fluctuations.

2. If the areas of the V-states are sufficiently close, head-tail interactions in the range $(3/8) < (\Gamma_1/\Gamma_2) < 8/3$ lead to "capture" or "merger" of like-signed vorticity regions.

2.2 A Vortex Model of the Geostrophic β-plane. (with Dr. J. McWilliams at NCAR)

Here the circulation of each vortex is modulated according to the β-effect; in our case linearly with the displacement from the origin

$$\Gamma_i = \Gamma_{io} + \beta y_i .$$

This modulation idea is a qualitatively new concept for point-vortex dynamics. Analytical results for a two point-vortex model were made by N. Zabusky and showed that a like-signed arrangement of vorticity had a "westward" drift and an unlike-signed arrangement had a long period

oscillation when initially titled. Calculations with many point vortices and with continuum pde models show qualitative agreement. This work was also supported by the Office of Naval Research under task NR 062-583. Further detailed comparison work is planned and a paper is in progress and will be completed before 1 March 1982.

2.3 Limiting V-states.

Pfo. Wu Hua-Mo has shown both analytically and computationally (with a new algorithm) that the "limiting" V-state (where the regions of positive vorticity and negative vorticity are contiguous) has a completely regular contour of finite extent. See Figure 1 for (1/4) of the contours. This work disproved the claim of Pierrehumbert [JFM, (1980) 99, 128-144] who found a cusped limiting contour.

3. MEETINGS AND VISITS

3.1 N. Zabusky visited the Laboratory for Applied Mathematical Physics at the Technical University in Lyngby, Denmark from 9/8/80 - 12/16/80. He was a Guest Professor and did work as described in Section 2.2 and also completed the manuscript, "Computational Synergetics and Mathematical Innovation."[4] This traces the history of the discovery of the soliton concept and its application in diverse areas of physics including fluid dynamics.

3.2 A paper on V-state scattering was given at the spring SIAM meeting in Troy, NY, Junr, 1981. A review paper on contour dynamics, and scattering was given at the Army Mathematicians Meeting at West Point Military Academy on June 11, 1981.

3.3 An invited paper was presented to the XV Sumposium on Advanced Problems and Methods in Fluid Mechanics, Jachranka, Poland, 9/81.

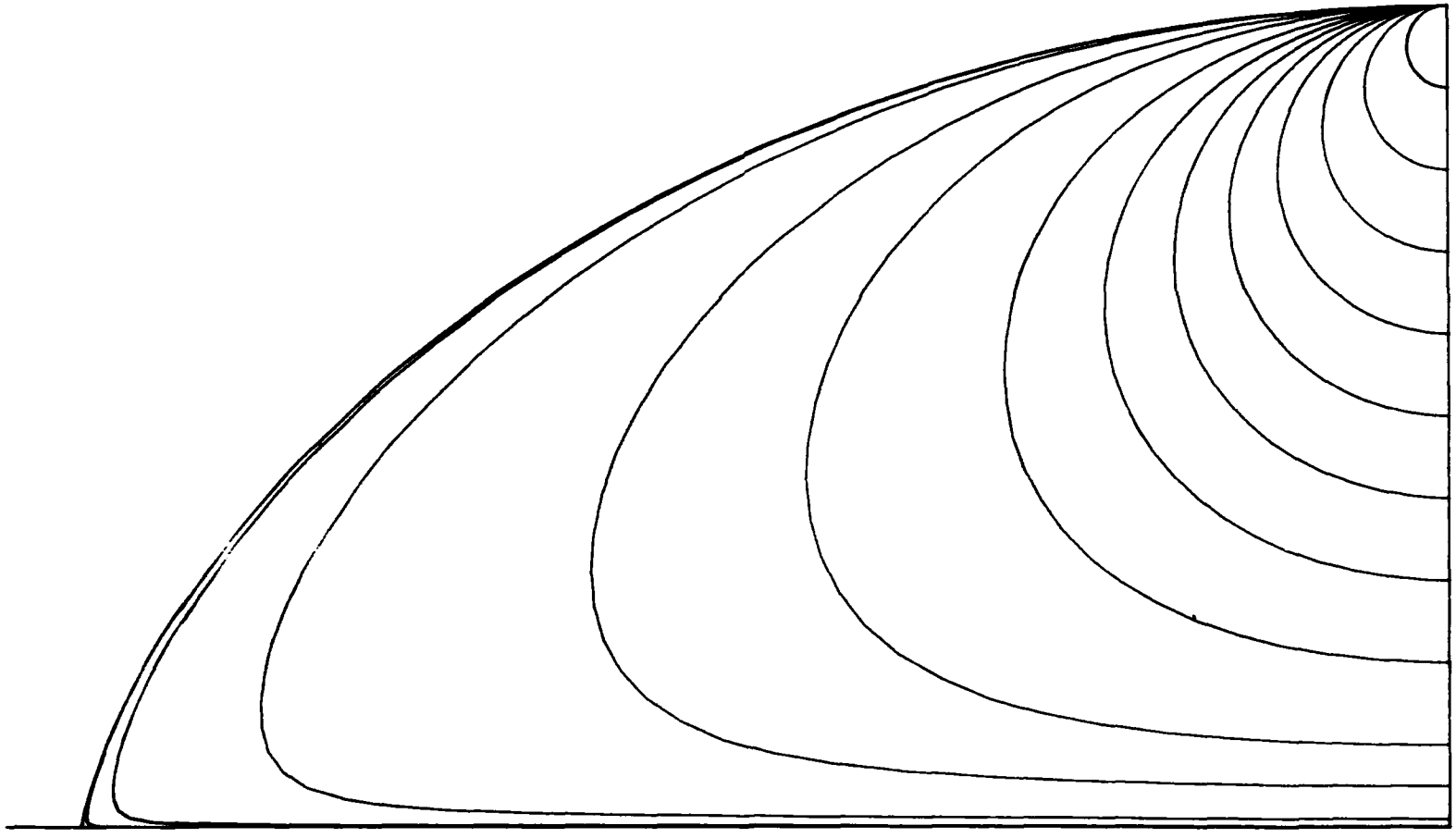
4. PUBLICATIONS SUPPORTED ALL OR IN PART BY THIS CONTRACT

1. Zabusky, N. J. and E. A. Overman, II, "Translation, interaction and scattering of Euler equation V-states via contour dynamics," Transactions of the 27th Conference of Army Mathematicians, ARO Report 82-1, 667-685.

2. Overman, E. A., II and N. J. Zabusky, "Translation, interaction and scattering of Euler equation V-states via contour dynamics." A more complete version than Reference 1; to be submitted for publication.

3. Zabusky, N. J., "Computational synergetics and mathematical innovation," J. Comp. Phys., October (1981).

Translating V-states, including the limiting case.
(Only 1/4 of the contours are shown. The remainder
are obtained by symmetry).



Limiting

Fig. 1.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